

PHYTOPATHOLOGY.—*An external dry rot of potato tubers caused by Fusarium trichothecioides*, Wollenw. C. O. JAMIESON and H. W. WOLLENWEBER, Bureau of Plant Industry. Communicated by C. S. Scofield.

Certain types of decay of potato tubers have been ascribed by various authors to the action of the fungus *Fusarium* (Clinton, 1895; Smith and Swingle, 1904). Conclusive infection experiments have been performed by several (Pizzigoni, 1896; Wehmer, 1897; Pethybridge and Bowers, 1908; Longman, 1909 and others).¹ In most cases *Fusarium solani* (Mart.), or a species thought to be a synonym of it, is said to be the real cause of the rot. The different kinds of decay described on the one hand, and the negative results often secured on the other, directed attention to a more complete study of the morphology of potato Fusaria and their differentiation. During this study, which was done in Germany, not less than fifteen species were isolated, of which nine have been published (Appel and Wollenweber, 1910). As a result of recent and as yet unpublished experiments at Dahlem-Berlin only two of the nine species have been found to be wound parasites of the stored tuber: *F. coeruleum* (Lib.); *F. discolor* var. *sulphureum* (Schlecht. s. sp.). Closely related to the latter is a new species, found in the United States and characterized by a peculiar injury known as external dry rot. This disease has been studied by Miss Jamieson during the past two years.

Attention was first called to the disease in February, 1910, in potato tubers sent from Spokane, Washington. Since then we have examined samples of similarly diseased tubers from the same locality, as well as from Iowa, Minnesota, Nebraska, and South Dakota. Symptoms of this disease have been noticed in the field at the time of harvesting potatoes, in one instance the estimated infection being about 10 per cent of the crop, but it is

¹ See also Appel and Kreitz. Der derzeitige Stand unserer Kenntnisse von den Kartoffelkrankheiten und ihrer Bekämpfung. Mitt. a.d. Kais. Biol. Anst. f. Land und Forstw., Heft 5, 1907. Berlin. (With lists of the more important references up to 1907), and Pethybridge and Bowers. Dry Rot of the Potato Tuber. The Economic Proceedings of the Dublin Society, vol. I, 14, 1908, p. 547-558. 1 Tab.

concerning the loss of potatoes in storage that complaint is most frequently heard.

Potatoes affected with this external dry rot are characterized by wrinkled, discolored, and somewhat sunken external spots, frequently but not always occurring at the "eye" end of the tuber, and varying in diameter from a few centimeters to several inches according to the progress of the disease. The color of these diseased areas is in general brownish, considerably darker than that of the normal epidermis and often having a slightly grayish cast. In a more advanced stage of the disease the epidermal tissue often breaks or cracks irregularly, exposing a substratum of fungus mycelium within. The surface of the tuber about the cracks may also be overgrown with a delicate pinkish-white, powdery growth, composed of fungus threads and spores. From sections made thru diseased tubers, the internal fleshy portion is seen to be seriously affected, often to a greater extent than is apparent from the external appearance. The internal discoloration is sepia brown, a cross section of a badly diseased potato often showing a pronounced contrast of shades varying from light to deep brown. As infection proceeds internal cavities are formed, from one to several centimeters in diameter, within which the fungus mycelium grows abundantly, presenting the same powdery appearance as noticed on the surface of the tuber. Gradually the whole substance of the potato becomes involved, until finally it is reduced to a dry, powdery, brownish-colored mass of broken-down cells, starch grains, fungus mycelium and spores. Tissue from various parts of infected tubers showed a fungus belonging to the genus *Fusarium* thruout the discolored portions as well as in the firmer tissue bordering upon these areas. A pure culture of this *Fusarium* was isolated from the inner tissue by the agar plate method. During our further investigations the same fungus has been isolated several times from dry-rot infected potatoes.

The following description and diagnosis of this *Fusarium* is now being added in the monograph of Dr. Wollenweber:

Fusarium trichothecioides Wollenw. In general appearance this fungus closely resembles *Trichothecium roseum* (Link); Conidia in nature as a rule not in sporodochia, but, in pure culture the

sporodochium or Pionnotes stage also occurs: Conidia of the former 1-3 septate, medium size, $15-26 \times 4-5\frac{1}{4}$ microns, formed as a slightly curved comma, ellipsoidally rounded on both sides; conidia of the latter type 3-5 septate, $24-42 \times 4\frac{1}{2}-5\frac{1}{2}$ microns; form of the *Discolor* type. Conidia masses and plectenchyma salmon colored to carrot red when slightly moist, but lighter and usually rosy-white when powdery dry and intermixed with mycelium. Yellowish to brown stromata may be formed. Conidiophores of the comma type, mostly irregularly branched, with prominent sterigmata, the arrangement of which is scattered, or especially at the top, trifurcate. Conidiophores in the sporodochia more highly developed, like those of *F. discolor*. Chlamydospores seldom occur, and when present are intercalary, in chains or single.

Causes decay of potato tubers, especially under storage conditions. Diseased spots sepia-brown within. The early stage shows a very brownish black discoloration of the layer bordering the sound tissue. Spokane, Washington; St. Paul, Minnesota; Dayton, Iowa; Alliance, Nebraska; and Spearfish, South Dakota.

The two stages of conidial development above mentioned give this fungus an individual place in the genus. Less developed spores of other species may occur under abnormal conditions, but disappear when grown on a favorable host; but *F. trichothecioides* as a rule produces this smaller form abundantly both in nature and in pure culture. Spores of this stage resemble (Fig. A, E, F) exactly *Trichothecium* (Link) Corda, described and figured by Corda.² The sterigmata of the conidiophores, often trifurcate at the tops (Fig. C), seem to indicate a relationship to Basidiomycetes. Most important for the determination of the fungus, however, is the development of the higher type (Fig. B) in pure cultures. It forms salmon-colored sporodochia of the well known tubercularia-like type on the surface of sterilized, not too moist grains of cereals and mature stems of plants. The conidiophores of these sporodochia (Fig. D) are verticillately branched and show

² *Icones fungorum*, 1838, p. 10, cum tab., IX, fig. 48, 49.

a striking contrast to the smaller form (Fig. C). All the intermediate grades from the comma stage (like *Trichothecium*) to the sporodochia stage are easily produced by a selection of media. Beginning with the higher (sporodochia) stage we can reduce the fungus to the inferior (comma) stage by means of a transfer of mycelium; on the contrary, spores of the comma type once or repeatedly transferred on grains or stems, will give normal sporodochia with three to five-septate spores, sharply pointed at the ends (Fig. B).

The relationship to the discolor group may be determined only by the higher form; a confusion of the new fungus with *F. discolor* and its variety "*sulphureum*" is impossible because *F. discolor* differs by producing a purple mycelium, while that of "*sulphureum*" is brimstone-colored, and both differ from *F. trichothecioides* by the absence of the comma stage.

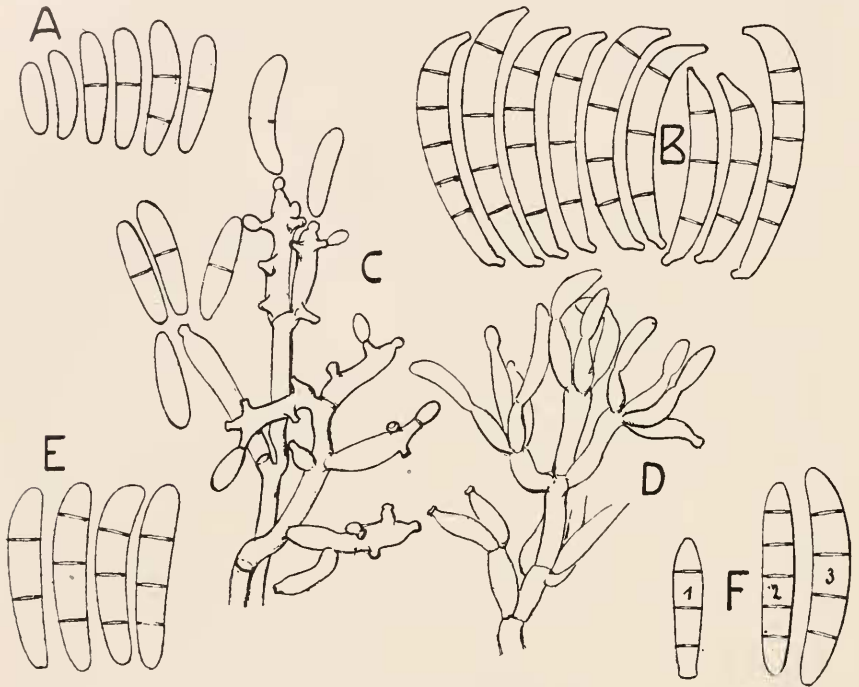
The occurrence of *F. trichothecioides* on other hosts is as yet unknown. A comparison with earlier studies of other authors shows that 5 different Fusaria cause similar tuber rots, 4 of which are fully described:³ *F. solani* (Mart.), *F. coeruleum* (Lib.), *F. discolor* var. *sulphureum* (Schlecht. s. sp.), *F. trichothecioides* Wollenw. Probably Miss Longman⁴ has dealt with a species different from the four. She names it *F. solani*, but to judge from her figures and her description, she had to do with a quite distinct species.

In order to prove the parasitic nature of *Fusarium trichothecioides*, inoculation experiments have been carried on under controlled conditions in our greenhouses during the past two seasons. Potato plants, grown in sterilized soil, from selected and disinfected seed were used, and pure cultures of *F. trichothecioides* inoculated into the stem just above the surface of the ground (Dec. 1910). In twelve days a wilting of the foliage was noticed accompanied by a yellowing of the leaves and a discoloration of

³ Appel and Wollenweber: "Grundlagen einer Monographie der Gattung *Fusarium* (Link)," Bd. VIII, Heft 1, m., 10 Textfig., 2 schwarz., 1 farbig. Doppeltafel. Berlin: P. Parey u. J. Springer. 1910. Preis, 10 M.

⁴ Longman, Sibyl: "The Dry-Rot of Potatoes," *Linnean Society's Journal*, Vol. XXXIX, Aug., 1909.

the tissue about the inoculation pricks. In three weeks time the fungus infection had produced a pronounced effect upon the plants, shown in the wilted condition of the foliage, in the constriction of the stem at point of inoculation, and in a brownish black



EXPLANATION OF THE FIGURE

A, E, F. Conidia of the comma-stage, grown on sterilized potato stems. F_1 seen from the back, F_2 , F_3 , extra large and highly septate. B. Conidia of the sporodochia-stage, grown on sterilized grains of corn (twenty days old). C. Conidiophore which in masses forms a dense growth on the surface of the medium like *Tricothecium roseum*, and produces spores shown in A, E, F. D. Conidiophore from a sporodochium, that forms the spore shown in B. Magnification 870.

discoloration of the tissue above and below the constriction. Upon the surface of the discolored area could be seen a growth of powdery slightly pinkish mycelium and spores. Microscopic examination and isolation showed this fungus to be *F. tricothecioides*.

cioides. Pure cultures of this same *Fusarium* were later obtained from tubers produced upon a plant diseased thru inoculation.

Further experiments are now being made to determine the most favorable conditions under which the infection of *F. trichothecioides* takes place. For this experiment sound healthy potato tubers of Burbank and Early Ohio varieties were selected, disinfected and placed in inoculation chambers. Two methods of inoculation were tried, one by stabbing the tuber with a thick needle and inserting fungus mycelium and spores from a pure culture of *F. trichothecioides*, the other by rubbing the surface with a platinum loop bearing the fungus. The ten inoculation chambers were then placed under different conditions of heat and moisture and examined at definite intervals. Thus far, results from this test indicate that of the two methods stabbing is the most effective, altho infection follows the rubbing of the fungus on the surface of the tubers. Discoloration of the tissue was noticed in the inoculation chambers after ten days and this was followed by a decay which penetrated into the tissue 2-3 cm. in twenty days. Rapid discoloration of the tissue was observed in both moist and dry chambers placed at a temperature of 10-12° C. In the drier atmosphere however, there was a deeper penetration of the decay into the tissue, than occurred at the same temperature under increased humidity. Two months after inoculation, the potato tubers were carefully examined and their appearance compared to the diseased specimens sent in from the field. Externally and internally the disease characteristics in field and laboratory specimens were similar. The brown grayish spots on the outside of the inoculated tubers frequently surround the "eyes," except in the case of the stab inoculations where the discoloration spreads about the wound. On the surface of the diseased tissue there is usually an abundant growth of pinkish powdery mycelium in the moist atmosphere, but very little of the external fungus growth in the drier air. The discoloration caused by the penetration of the fungus and extending several centimeters below the epidermis varies from light to dark sepia brown in color, the darkest portion forming a band which surrounds the cavities. In every

instance the decay appears to work from the surface inward. From results of this experiment it is clear that conditions of temperature and moisture undoubtedly play an important part in the beginning and in the progress of infection, and a better understanding of these conditions may prove of great value in attempting to control this dry rot disease especially among potatoes kept in storage.

SUMMARY

1. *F. trichothecioides* Wollenw. is a wound parasite capable of destroying potato tubers.
2. This fact is proved by the inoculation experiments of Miss Jamieson.
3. This disease is clearly differentiated from the wilt and dry rot ascribed by Smith and Swingle to *Fusarium oxysporum* Schlecht.